UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

RESULTS OF RICE EXPERIMENTS AT CORTENA, 1923

AND

PROGRESS IN EXPERIMENTS IN WATER GRASS CONTROL AT THE BIGGS RICE FIELD STATION 1922-23

BY

CARROLL F. DUNSHEE *and* JENKIN W. JONES

BULLETIN No. 375
February, 1924

UNIVERSITY OF CALIFORNIA PRINTING OFFICE
BERKELEY, CALIFORNIA
1924

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* The rice investigations conducted at Cortena, Colusa County, are administered by the Division of Irrigation Investigations and Practice of the College of Agriculture with the assistance and advice of the following rice committee appointed by the Director of the Agricultural Experiment Station: Frank Adams, chairman, P. L. Hibbard, J. W. Jones, Superintendent Biggs Rice Field Station of the Bureau of Plant Industry, P. B. Kennedy, W. W. Mackie, Chas. F. Shaw, and W. W. Weir. During 1923, Messrs. Louis Rathbun, George Houx, and Raymond Houx, rice growers, were especially helpful with suggestions and in the loaning of equipment. As during the previous season, irrigation water was furnished free by the Glen–Colusa Irrigation District, and Carroll F. Dunshee continued in immediate charge.

The investigations conducted at the Biggs Rice Field Station are planned, financed, and directed by the Office of Cereal Investigations of the Bureau of Plant Industry, U. S. Department of Agriculture, and are conducted by Jenkin W. Jones, Agronomist.

INTRODUCTION

Water grass (*Echinochloa crus-galli* and varieties) is the most troublesome weed in the California rice fields. This grass was present in California when the rice industry first started, and has spread from year to year in spite of efforts both by hand-pulling and by cultural practices, to keep it under control. The conditions under which rice is grown in California are almost ideal for the growth and distribution of water grass. Not only does this grass reproduce rapidly, but its seeds are inclosed by oily hulls which tend to protect them against unfavorable climatic conditions.

Rice land in California is spoken of as either "new" or "old" land. New land is that which has never been seeded to rice. Old land is that which has produced two or more rice crops. Practically all, if not all, of the old lands—and these constitute the major portion of the rice acreage—are quite foul with water grass.

On this foul land it is practically impossible to grow profitable rice crops by the old method of irrigation. This consists of irrigating and draining the land at frequent intervals until thirty days after the rice has emerged. The land is then submerged about six inches, the water being held at that depth until the fields are drained for harvest. Under this method of irrigation on foul land, the water grass competes successfully with the rice crop, and the reduced yields which follow are often unprofitable.

Rice growers observed a few years ago that water grass was controlled or suffocated to a marked extent by water if the young plants or seed were completely submerged for some time. At the same time they noticed that rice seed germinated under water and that the young seedlings stretch upward through the water and later make a normal growth. These observations led to new methods of irrigation for rice when grown on foul land.

The first of the new methods, and the most common, consists of sowing the rice broadcast on a smooth seedbed and immediately submerging the land four to eight inches. The water is held at this depth until the land is drained for harvest.

The second method consists of preparing a reasonably smooth seedbed, submerging the land to a depth of four to eight inches, and then sowing the rice broadcast in the water, which is held at the depth named until the land is drained for harvest.

A third method, which is much less common, consists of drilling or broadcasting the rice. The land is immediately irrigated and then drained. It remains thus until the rice and water grass seedlings emerge. Then the land and the young seedlings are submerged four to eight inches, the water being held at that depth until the land is drained for harvest.

Of these three methods of irrigation, the first and second are quite effective in the control of the common water grasses. The third is less effective. The first method is used most extensively on old rice land in California. It has been used by some growers for several years.

This bulletin gives the results of investigations and experiments on water grass control and related subjects conducted by this Station at Cortena, Colusa County, during the season of 1923, and the results of experiments on water grass control conducted by the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, at the Biggs Rice Field Station during the seasons of 1922 and 1923. While these investigations have been conducted separately, the work at the two field stations has been correlated in such a way as to eliminate unnecessary duplication. For all practical purposes, therefore, the work at the two stations constitutes one study, and the results obtained can appropriately be published in a single bulletin. This has been made possible through a coöperative understanding between the California Agricultural Experiment Station and the Bureau of Plant Industry.

I. RESULTS OF RICE EXPERIMENTS AT CORTENA IN 1923

By CARROLL F. DUNSHEE

This progress report of rice experiments carried on during the crop season of 1923 by the University of California College of Agriculture at the temporary field station near Cortena, Colusa County, covers work which was in the main a continuation of that started in 1922, a progress report of which appeared as Bulletin 354 of the University of California Agricultural Experiment Station.

Two new lines of work were started in 1923, one being to determine the water requirements of rice, and the other to determine the best follow-crops for rice. C. F. Shaw has continued his studies on the effect of rice-growing on the physical condition of the soil and P. L. Hibbard has studied the effect of rice-growing on the soil bacteria.

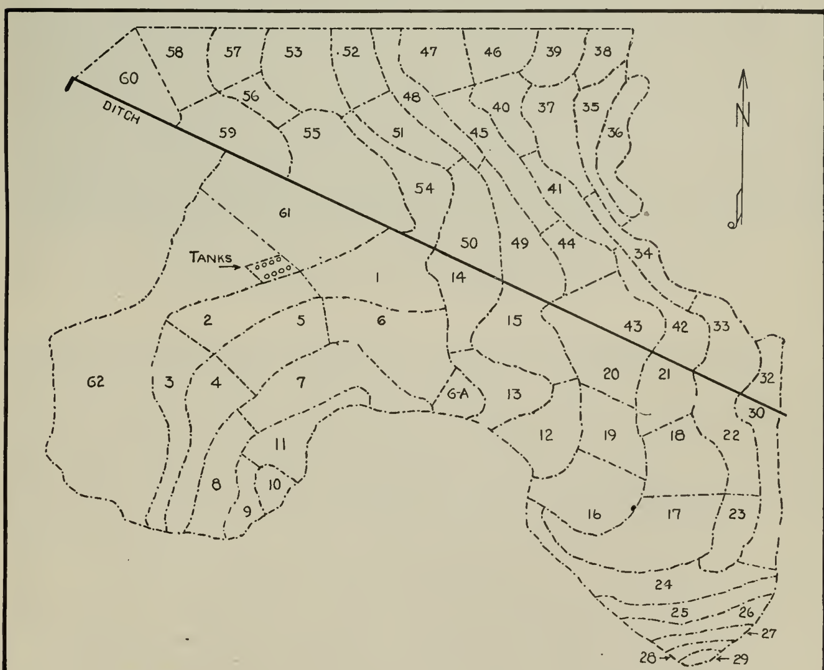

Fig. 1.—Map of temporary rice experiment station, Cortena, showing arrangement and location of plots.

PREPARATION OF FIELD AND SEEDING

The field preparation and the method of seeding were the same as practiced in 1922. Caloro seed was used, however, in place of Early Wataribune. The standard rate of seeding was 150 pounds to the acre. Two plots, however, were seeded at the rate of 200 pounds to the acre, and two plots were submerged and seeded in the water at the rate of 135 pounds to the acre. Plots not requiring submergence at a later date were submerged by May 1.

EFFECT OF METHOD OF SEEDING AND SUBMERGENCE ON WATER GRASS CONTROL

Submergence immediately after broadcasting.—During 1922 the plots in this series of experiments were submerged to depths of two, four, six, and eight inches. It was found impracticable to submerge plots to a depth of two inches; therefore, this treatment was abandoned in 1923 and two ten-inch submergence plots substituted.

A somewhat different problem was encountered this season in that three inches of rain fell between March 31 and April 9, after the seedbed had been fully prepared. This rain caused considerable barnyard grass (*Echinochloa crus-galli*) and other water grasses to sprout, making it necessary to double disk the field before seeding. This disking killed most of the sprouted water grass seeds, but those not killed in this way were found to be very difficult to control. This experience added weight to the impression that it is difficult to control barnyard grass by continuous submergence after it has established roots in the soil.

In plots submerged ten inches, no barnyard grass appeared above the surface of the water. The plots submerged eight inches had a few scattering plants; those submerged six inches, a much larger number, though not enough to influence the yield, while those submerged four inches were quite foul. It was found impossible to control the small sedge or Umbrella plant (*Cyperus difformis?*). This was considered very troublesome in 1922 and spread so this past season that it was present in all plots. It was estimated that the yield of several of the plots was reduced as much as 50 per cent by this weed. In fact, the great reduction in yield this season is believed to be due largely to its presence, since excellent stands of rice were obtained in all plots up to the time the sedge began to show its effect about June 15.

Broadcasting in water.—The effect on weed control was the same as in the plots submerged after broadcasting.

Submergence immediately after drilling.—A very poor stand of rice resulted from this treatment. There was complete control of the barnyard grass in plots submerged eight inches. Some grass, however, appeared in the plots submerged six inches, and considerably more in plots submerged four inches. The stand of sedge in all these plots was exceptionally thick. It seems clear, therefore, that a poor stand of rice is favorable to the growth of sedge.

Fig. 2.—Beginning of submergence of rice plots.

Submergence after germination.—In this experiment the seed was drilled in and the plants submerged to the required depth when they were about one inch high. Good stands of rice were obtained in all plots up to the time of submergence. Later, however, the plots became foul with barnyard grass, and at maturity the stand of rice was poor. The sedge was as thick in these plots as in those broadcasted and then submerged.

TABLE 1

SUMMARY OF RESULTS SHOWING EFFECTS OF METHODS OF SEEDING AND DEPTHS OF SUBMERGENCE ON WEED CONTROL AND YIELDS OF RICE

Plots	Seeding		Submergence		Acre-yields in pounds			Compared with checks	
	Date	Method	Date	Depth, inches	1922	1923	Average	Gain	Loss
60, 41	May 1	Broadcast on soil	May 1	10	....	1765	....	630	....
58, 44	May 1	Broadcast on soil	May 1	8	2766	1871	2318	1183	....
57, 45	May 1	Broadcast on soil	May 1	6	3318	1841	2579	1444	....
53, 47	May 1	Broadcast on soil	May 1	4	2733	1448	2090	955	....
59, 50	May 1	Broadcast in water	May 1	8	2453	2042	2247	1112	....
55, 40	May 1	Broadcast in water	May 1	6	2041	1583	1812	677	....
55, 46	May 1	Broadcast in water	May 1	4	2952	1591	2271	1136	....
54, 49	May 1	Drilled	May 1	8	2358	1588	1958	823	....
51, 48	May 1	Drilled	May 1	6	1770	1442	1606	471	....
52, 39	May 1	Drilled	May 1	4	1716	709	1212	77	....
33, 42	May 1	Drilled	May 26[a]	8	2142	1423	1782	647	....
34, 35	May 1	Drilled	May 26[a]	6	1079	1045	1062	....	73
36, 37	May 1	Drilled	May 26[a]	4	1368	966	1167	32	....
6A, 38[b]	May 1	Drilled	June 20	6	1347	924	1135	Ch'k	....

Seeding was at the rate of 150 pounds per acre

[a] Plots irrigated twice and submerged when about one inch high.

[b] First irrigation on May 3, followed by four irrigations prior to submergence thirty days after emergence of the plants. These plots were exceedingly foul with rice weeds.

Fig. 3.—Arrowhead (*Sagittaria latifolia*). This weed is not troublesome in good stands of rice, being found in thin stands and in irrigation ditches. Continuous submergence does not control it. Summer fallow aids in its control.

EFFECT OF DATE OF SEEDING AND SUBMERGENCE ON WATER GRASS CONTROL AND YIELDS OF RICE

On account of late spring rains, the earliest seeding practicable in 1923 was April 25 instead of April 15, as planned. Somewhat better yields seem to have been obtained from this early seeding than from seeding on May 1 and May 15. Distinctly better yields were obtained from the earlier seeding than from that on June 1. The only difference noted in weed control was that the sedge was considerably thicker in plots submerged June 1. Resulting yields are presented in table 2.

TABLE 2

SUMMARY OF RESULTS OF EXPERIMENTS ON THE DATE OF SEEDING AND SUBMERGENCE OF RICE

Plots	Seeding		Submergence		Acre-yields in pounds		
	Date	Method	Date	Depth, inches	1922	1923	Average
1, 20	April 25[a]	Broadcast on soil	April 25	6	3664	2788	3226
6, 19	May 1	Broadcast on soil	May 1	6	2558	2338	2448
14, 16	May 15	Broadcast on soil	May 15	6	2648	2388	2518
13, 17[b]	June 1	Broadcast on soil	June 1	6	2069	1137	1603

[a] April 15 in 1922.

[b] Yields in plots 13 and 17 reduced materially in 1923 by annual sedge.

Fig. 4.—Sprangle top (*Leptochloa fasicularis*). Can be controlled by continuous submergence. Where not controlled it is a serious pest. Grows two to four feet high. Matures seed in September.

MISCELLANEOUS EXPERIMENTS

In all plots concerned in these experiments submergence was completed by May 1. Unless otherwise noted, seeding was at the rate of 150 pounds per acre.

Weed and cat-tail control by heavy seeding.—Very thick stands of rice resulted from broadcasting at the rate of 200 pounds to the acre and submerging to a depth of six inches. There was no control of cat-tails, but there was a slight control of the sedge. Barnyard grass control was similar to that in other continuous submergence plots.

Fig. 5.—Joint grass (*Paspalum distchum*). This weed is becoming a menace, especially in old rice fields and in ditches. It usually starts in the unplowed portions of fields. Continuous submergence does not control it. Can be held in check by deep plowing and fallow. The stalk is usually one to two feet high. Matures seed in September.

Seed broadcasted on rice stubble.—Very poor stands resulted from this treatment. Weed and cat-tail growth became very thick and by the time the crop was mature it was impossible to use a binder.

Seed broadcasted in water on rice stubble.—The stand resulting from this treatment was similar to that in other plots which were not plowed. Because of cat-tail and other weed growth it was impracticable to harvest the crop.

Rice after fallow.—These plots had been in rice continuously for four years previous to 1922, but were fallowed that year. They were plowed in the spring of 1922 and again in March of 1923. Excellent seedbeds resulted from this last plowing. The rice was broadcasted

and the plots submerged immediately to a depth of six inches. Poor stands were obtained in all plots. There was only a scattering of barnyard grass, but sedge, red stem (*Ammania coccinea*), and sprangle-top (*Leptochloa fascicularis*) were very prevalent.

Rice broadcasted in water at the rate of 135 pounds to the acre.—In 1922 it was observed that rice broadcasted in water at the rate of 150 pounds per acre gave stands that were perhaps too thick for maximum yields. Therefore, in 1923, two plots were submerged and the seed broadcasted at the rate of 135 pounds to the acre. The sedge reduced the yields in all treatments to such an extent that it was impossible to note any difference between the two rates of seeding.

Fig. 6.—Barnyard grass or water grass (*Echinochloa crus-galli*). This shows the late form of barnyard grass. It is yellowish-white in color and matures seed late in September. The plant grows one to three feet high. It is the most difficult form of *Echinochloa crus-galli* to control.

WATER REQUIREMENTS OF RICE PLANTS

In order to gain information on the water requirements of the rice plant, experiments were started to determine the amount of water lost through evaporation, through seepage in the soil, and by transpiration through the leaves. An area 25 by 50 feet was leveed off from the rest of the field, and nine concrete tanks thirty inches in diameter and four feet deep were placed in the soil. All of these tanks were painted on the inside with a waterproof paint, and with the exception of two tanks used for seepage determinations, were sealed at the bottom with three inches of concrete. One tank, which was so sealed at the bottom,

but in which no rice was planted, was used for an evaporation tank. Two tanks, having the bottoms sealed, were planted with rice and used to determine the amount of moisture lost by transpiration and evaporation. Two tanks, having the bottoms sealed and the tops covered with celluloid, were planted with rice and used to determine the loss by transpiration. The area surrounding these tanks was

TABLE 3

SUMMARY OF RESULTS OF MISCELLANEOUS EXPERIMENTS

Plots	Treatment[a]	Acre-yields in pounds		
		1922	1923	Average
2, 5	Seed broadcasted at rate of 200 pounds per acre and submerged six inches in effort to control weed and cat-tail growth	1994	2331	2162
15, 21	Seed broadcasted on stubble and submerged six inches	1728	........[b]	864
12, 18	Rice stubble submerged six inches and seed broadcasted in water	1139	........[b]	569
23, 43	Seed broadcasted in six inches of water at rate of 135 pounds per acre	....	1568	....
7, 9, 11	Seed broadcasted and submerged six inches after fallow in 1922	....	1210	....
22, 24-30, 61	Seed broadcasted and immediately submerged six inches	2312	1895	2103

[a] Seeding and submergence completed on May 3. Unless otherwise noted seeding was at the rate of 150 pounds per acre.

[b] Cat-tail and other foul growth made it impracticable to cut rice.

seeded with rice and submerged, in order to simulate field conditions. Water was measured into the tanks from day to day during the growing season. Two tanks were used in an effort to determine the value of copper-sulfate in the control of scum or algae, but the waterproof coating applied to the tanks, or some other condition, prevented algal growth. These experiments must necessarily be continued for some time before definite conclusions can be drawn. Mention of them is made here merely to indicate to growers the type of studies under way in addition to those for which results are given.

The low temperatures during the early part of the growing season in 1923 may be responsible for part of the low yields obtained at Cortena and throughout the valley. Both the maximum and minimum temperatures were considerably lower than during the same period in 1922. This may have kept the plants from being as thrifty as they would have been with higher temperatures.

TABLE 4

MONTHLY AVERAGE OF MAXIMUM AND MINIMUM TEMPERATURES* AT CORTENA, CALIFORNIA

Month	1922		1923	
	Maximum	Minimum	Maximum	Minimum
March	....	....	70.29	42.58
April	....	....	69.69	48.10
May 1-11	....	....	82.18	51.90
May 12-31	85.50	58.00	78.95	51.50
June	90.13	61.20	83.50	57.30
July	93.84	66.96	92.74	63.60
August	90.74	50.67	91.54	62.70
September	92.96	55.88	87.30	60.33
October	73.03	50.67	77.38	53.70

* Recording of temperatures started May 12, 1922.

EXPERIMENTS WITH FIELD CROPS

Thirteen varieties of field crops were planted on land which had been in rice continuously for four years but which had been fallowed in 1922. Owing to the fact that the method of irrigation followed proved to be faulty, satisfactory results were not obtained. These trials will be resumed in 1924 under more favorable cultural conditions.

STUDIES OF THE PHYSICAL CONDITIONS OF RICE SOILS*

Studies were continued through the year on the physical character of the Willows clay and Stockton clay adobe, comparisons being made between soils taken from fields that had been in rice for some years and fields that had never been in rice or in any irrigated crop. These studies showed the same inconclusive results as those carried out last year; no evidence has as yet been obtained to show that any material

* Charles F. Shaw of the Division of Soil Technology furnished this brief progress report.

change has been brought about in the physical character of the soil through the submergence incidental to rice culture.

In an endeavor to determine the amount of expansion and contraction that brings about the shrinking, cracking, and granulation that occur on these soils, expansion studies were made using the auxographic method devised by the Arizona Experiment Station. The results showed that the Willows clay, which had produced a rice crop, had a more rapid expansion than the same soil which had never been irrigated. The total amount of expansion, however, was found to be somewhat greater in the unirrigated lands. The studies of the Stockton clay adobe from Biggs showed the opposite effect, the rate of expansion of the soils from the rice plots being slower, but the total amount greater than that of the samples from the Experiment Station yard which had never been in rice.

Mechanical analyses are being made by a new method which shows the amounts of the finest clay particles in the soil. The results to date appear to be as inconclusive and contradictory as those on expansion and contraction measurements and those reached last year. In short, there is no positive experimental evidence to show that rice culture has caused any measurable change in the physical character of these soils.

CHEMICAL STUDIES ON WATERS AND SOILS*

A. WATER BEFORE AND AFTER USE ON RICE

(1) *On the experiment plots at Cortena.*—The canal water, primarily derived from the Sacramento River, was nearly constant in composition throughout the season. It contained slightly more salts at the end of the summer than in the spring. The water draining from the rice plots contained somewhat more salts than the canal water, and it also changed very little during the season. It was at all times of good quality for irrigation purposes. Evidently the salts in the soil were not near enough to the surface to be measurably absorbed by the water that flowed over the fields.

(2) *On commercial rice fields near Cortena.*—The water supplied to these fields was from the same canal which supplied the experimental plots at Cortena. In some places, the drainage was similar to

* The report of rice investigations at Cortena in 1922, published as Bulletin 354 of this Station, contained a preliminary report on water and soil analyses by P. L. Hibbard of the Division of Plant Nutrition. A complete report on these studies, together with a report by the same author on changes of bacterial flora in rice soils, is included herewith.

that at Cortena, though in all cases it contained somewhat more soluble matter. But the drainage from other fields contained five to ten times as much soluble matter as the intake water. Generally the highest amounts of salts in the drainage were found in the early part of the season. In other words, the first run-off carried away most of the soluble salts that were near enough to the surface of the land to be affected by the rice flooding. Consequently, as the season advanced, the drainage water contained less and less soluble matter.

(3) *On rice fields in Sutter Basin.*—By the assistance and courtesy of the Sutter Basin Company, water samples were taken throughout the season from the intake at Sacramento River, from their main drain, and from the inlet and outlet in certain rice fields.

The river water was essentially the same as that at Cortena, showing a very slight increase of soluble matter during the summer. The outflow water at the main drain carried much more soluble salts than that at Cortena, but it showed the same sort of decrease in soluble matter toward the end of the season, when it contained about one-third as much as at the beginning of irrigation.

The water on and off certain individual rice fields showed the same general changes as were observed near Cortena, nearly uniform composition of the intake water, and a gradual lessening of the amount of salts in the drainage water as the season advanced. Rather large variations were recorded in the composition of the drainage waters of these fields from week to week, being sometimes higher, and sometimes lower in salts. These sharp changes may have been caused by variations in the weather and by variations in amounts of water used.

Cause of the increase of salts in the drainage water over the amount in the intake water.—The drainage waters in all places and at all times carried more soluble matter than the water going on the land. Part of this increase was due to concentration by evaporation, but most of it must be attributed to substances dissolved out of the soil. As most of these soils are known to have contained alkali salts before rice culture was begun, it was to be expected that water passing over them would carry away some of those salts. Since some of the salts are objectionable, the land is to that extent improved by the rice culture.

General character of the salts in the waters.—The Sacramento River water contains small amounts of the bicarbonates of calcium and magnesium, a little sodium chloride, much less sodium sulfate, and a little sodium bicarbonate. The last named salt determines the character of the water. It has primary alkalinity, the usual quality of water from regions of primary rocks such as granites or others

having a considerable amount of the silicates of sodium or potassium. Such water, when evaporated to dryness, leaves an easily soluble residue of sodium carbonate, the so-called black alkali, which is very undesirable in soil. However, the amount of it in Sacramento River water is so small that it is relatively harmless.

The drainage waters from these lands contain very little sodium sulfate, a fairly large amount of the bicarbonates of calcium, magnesium, and sodium, and generally considerable sodium chloride, with calcium and megnesium chlorides sometimes. The chlorides are the most variable constituents of these drainage waters; since they are largely derived from the soils over which the waters flow, variation is to be expected.

B. CHANGES PRODUCED IN THE ALKALI CONTENT OF THE SOILS BY THE IRRIGATION WATER USED ON RICE

(1) *On the experiment plots at Cortena.*—Samples of soil were taken before planting and after harvest from as nearly the same locations as possible. Most of them were taken to four feet, but some were taken down to twelve feet. Each foot was kept and analyzed separately. Samples were also taken from an adjoining field supposed never to have been in rice or to have been flooded. There was considerable variation in the amounts of salts in the samples from different holes on both old and new land. In some places there was little in either, but in general there was more saline matter in the surface two feet of the new land than in a similar portion of the old land. Below the fourth foot there were similar amounts in both. But in view of the variability of these soils, it seems unwise to consider that the number of samples taken was sufficient to show the true composition of these soils. Hence it is not safe to assume that the amount and kinds of salts in the different plots were originally the same. On the other hand, we have no means other than this comparison of new and old soils to show the effect of the rice culture on the salts.

In most parts of the old land, there is little alkali and not much salt in the upper two feet, and with one exception, little difference in the samples taken before planting and after harvest. In cases where there were notable amounts of chlorides near the surface before planting, the after-harvest samples showed similar concentrations one or two feet lower in the soil with a corresponding reduction near the surface. This change in location of the salts is regarded as being due to the leaching effect of the irrigating water. Samples taken before

and after the season, from four feet down to twelve feet, were as nearly alike as samples taken at different times could be expected to be. There was no evidence of leaching below the fourth foot. It seems probable that the irrigating water of previous years had already removed most of the salts from the upper two or three feet of these soils, before this season's work was started; also, that the flooding incident to rice culture will only very slowly remove the salts from the deeper portions of these tight clay soils. Whether these lower layers of saline matter will come to the surface if the soil is again used for crops other than rice cannot now be foretold. If such rise of alkali should occur, it is probable that another period of rice culture with flooding would carry away much of the alkali and leave the soil more free of salts.

It is concluded that in these clay soils, most of the salts removed by rice culture are carried away in the surface run-off, rather than in the underground drainage.

(2) *On rice lands in Glenn County.*—Many samples of soil from rice lands near Princeton and Deleven were taken in December, 1921. Though these samples varied greatly from one hole to another, it is plain that in many places there were very small amounts of salts in the surface one to two feet, and a larger quantity of salts lower down. These lands have been flooded during two or three previous years of rice culture. The soils are similar to those at Cortena and the analyses indicate similar effects produced by rice flooding. One notable difference is in the large amount of sulfates in the Glenn County soils, as compared with the very small amount of sulfates in the Cortena soils.

(3) *On lands in rice in Imperial Valley.*—These soils are calcareous silts very much more pervious to water than the clays of the Colusa and Glenn County rice fields. This difference in perviousness has produced very different effects where irrigation by flooding has been practiced. Soil samples were taken before planting and after harvest, to six-foot depths, each foot being tested separately. There was no run-off from this soil, so that the only possible movement of water was downward. Samples of water from the surface of the plots varied little from the water supplied to the plots, so that the changes produced must be ascribed to leaching. The soil had not recently been flooded. It contained, before planting, large amounts of sulfates and chlorides, somewhat uniformly distributed throughout the upper six feet. The samples taken after harvest had little chloride in the first four feet, and little sulfate in the first two feet. But there was some increase in the amount of these salts, particularly in sulfates,

at a depth of five and six feet. In some cases, the chlorides seem to have been carried down below the sixth foot. The sulfate was carried along much more slowly by the leaching water.

From these results, it sems probable that the flooding incident to rice culture would, in two or three years, carry the alkali salts in these soils so far below the surface that they would not again be troublesome to ordinary crops and perhaps not to trees.

C. GENERAL CONCLUSIONS REGARDING WATERS AND SOILS

(1) The irrigating water from the Sacramento River is of good quality and varies little throughout the season.

(2) Drainage from rice fields which have been flooded for two or more years is likely to be of fairly good quality for irrigation. But if the soil contains much alkali or salts within two feet of the surface, some or much of these soluble substances will be carried off in the drainage, so that sometimes it may be unsuitable for irrigation.

(3) Considering the fact that rice is relatively tolerant of saline water, it seems feasible to use drainage from one field to irrigate the next lower field, and so on until the final drainage becomes too saline for use.

(4) There seems to be little percolation of the water down through the clay soils, so that salts in those soils two feet or more below the surface will be removed only very slowly by the flooding practiced in rice culture. In more easily penetrated silts or sand there is sufficient percolation of the water to carry away most of the objectionable salts from the region of plant roots into the under drainage within a few years.

(5) The original soils at Cortena contain much saline and alkaline matter down to a depth of at least twelve feet. There is great variability in the distribution of this soluble matter throughout the soil, in places very near to each other.

(6) Those soils which have been flooded for three or four years have lost most of the alkali of the upper two feet, though there is still a considerable amount in some places. Below three feet, there is little evidence of change.

(7) The results of this year's work do not indicate that the flooding has caused any great change in the amount or location of the salts in the soil at Cortena, except that chlorides near the surface have gone down one or two feet lower. No change could be noted below four feet.

(8) On the porous soils of Imperial Valley, rice flooding in one season has greatly diminished the alkali and salts in the upper four feet.

(9) When alkali soils are flooded, the chlorides are most rapidly removed. Sulfates may require two or three times as long as chlorides, and carbonates ten or twenty times as long.

CHANGES IN BACTERIAL FLORA OF RICE SOILS*

This report is concerned with changes in the soil bacteria and fungi produced by the conditions of rice culture.

For this work, special soil samples were taken in November, 1922, shortly after the rice was harvested. These samples were taken from a rice plot and from a fallow field nearby which had not been flooded in 1922. In both cases, the soil samples considered represented depths from 0 to 8 inches and from 8 to 16 inches.

The studies of bacteria have been conducted by A. R. Davis of the Division of Plant Nutrition, with assistance from others. In detail, the results are as follows:

(1) The total number of organisms in the surface soil of a rice plot is about one-fourth the number in the fallow soil. The subsoil of the rice plot has about half as many as the subsoil of the fallow field.

(2) Comparison of different forms in fallow and rice soils:

(*a*) The cellulose destroying organisms seem to be slightly, but not significantly, more effective in the fallow soil.

(*b*) Denitrifying organisms are practically the same in both the rice and the fallow soils.

(*c*) Ammonifying power is good in both fallow and rice soil, perhaps a little stronger in the former.

(*d*) Nitrogen fixation is much superior in the surface of the fallow soils, but in the subsoil there is little difference between the rice soil and the fallow soil.

(*e*) Nitrification of ammonium salts is practically the same in the fallow and in the rice soils.

Since the number of samples of soil that were examined was small—twelve of the rice soil and twelve of the fallow soil—and since only one set of samples was studied, it sems unwise to draw sweeping conclusions from this one season's work. The validity of the results is

* This report also has been prepared by P. L. Hibbard.

not questioned, but too little work has been done and too few samples examined to warrant any positive statements. With these reservations, the following conclusions are drawn:

Summary regarding bacterial flora.—In most respects, there seems to be no very great difference between the fallow and the rice soils as regards micro-organisms. Though some kinds of bacteria are less active in the soil which has been flooded, it appears very probable that this soil will soon produce successfully again ordinary grain crops. The rice soil is most likely deficient in nitrates, so that some months, perhaps years, must elapse before the soil is again well supplied through the usual soil building agencies. On the whole, there is little in this study to indicate that the soil has been permanently injured by rice culture.

II. PROGRESS IN EXPERIMENTS ON WATER-GRASS CONTROL AT THE BIGGS RICE FIELD STATION, 1922-23

By JENKIN W. JONES
Agronomist, Cereal Investigations, U. S. Department of Agriculture

SCOPE AND METHOD OF EXPERIMENTS

Expermients in water-grass control were first conducted at the Biggs Rice Field Station, Biggs, California, in 1916. Cultivation was given after spring and summer irrigation to germinate the grass seed. These experiments showed that water grass could be controlled to a marked extent by fallowing the land and giving it a spring plowing after spring irrigation, followed by summer plowing after summer irrigation. But this method of control involved considerable labor and expense, so it never became a general practice on commercial fields. When foul land was fallowed, however, it usually was spring irrigated to germinate as much grass seed as possible before being plowed.

Experiments to control water grass by early submergence were started on the Biggs Station in 1921. The results obtained in that year were reported in U. S. Department of Agriculture Bulletin No. 1155.

More extensive experiments in water-grass control, different seeding practices, and different methods of irrigation were conducted at the Biggs Rice Field Station during the crop years 1922 and 1923. The present paper is a progress report on the results of these experiments.

The term water grass when used in this report includes all forms of barnyard grass (*Echinochloa crus-galli* and varieties), except the white or ''Japanese'' water grass.

The work reported covers (1) experiments on immediate submergence after seeding, including the effect of sowing broadcast on the soil and in the water and the effect of drilling seed; (2) experiments on submergence after the rice has emerged, including comparison of broadcasting and drilling seed, and comparison of spring-plowing and disking stubble; (3) experiments on rate of seeding and method of irrigation; (4) experiments on seedbed preparation, includ-

ing comparison of the effects of good preparation and no preparation, and the control of cat-tail by heavy seeding; and (5) experiments on rate-of-seeding with three varieties of rice. In most of these experiments the dates of seeding and depths of submergence also were varied.

During the crop year 1922 the temperature was favorable for rice production, but during the crop year 1923 the temperature was too cool for maximum yields of rice.

These experiments are being conducted to determine, if possible, the best method of seedbed preparation, date and rate of seeding, and date and depth of submergence, for rice grown by continuous submergence after broadcast seeding or when submerged soon after the rice emerges. They were designed also to study the effect of the different irrigation methods on the control of water grass and on yields of rice. The experiments have not been conducted long enough to warrant definite conclusions. However, the results obtained during the crop years 1922 and 1923 should be of interest to rice growers in California.

None of the rice sown broadcast was harrowed after sowing. On plots submerged at specified depths the water was maintained at as near the depths stated as was possible under field conditions, until the land was drained for harvest. All plots were sown at the rate of 150 pounds per acre unless otherwise stated. The few white water grass plants which appeared were pulled in all experiments except No. 4.

EXPERIMENTS ON IMMEDIATE SUBMERGENCE AFTER SEEDING

These experiments were conducted in 1922 and 1923, on land that had been continuously cropped to rice, in the fertilizer experiments, from 1913 to 1920, inclusive. In 1921 the land was fallowed. The 1922 crop, therefore, was the ninth rice crop in ten years and the 1923 crop the tenth rice crop on this land in eleven years. In the spring of 1922 the fallow land was double-disked, harrowed, and dragged. For the 1923 crop the land was spring plowed, harrowed, and dragged. In both years these tillage operations prepared a good seedbed.

In table 1 are shown the annual and average acre yields obtained from broadcasted seed sown on different dates, and immediately submerged to different depths in the years 1922 and 1923.

The yields given are the average of two tenth-acre plots in each case except the check plots, where they represent the averages from four tenth-acre plots.

TABLE 1

ANNUAL AND AVERAGE ACRE YIELDS OF CALORO RICE ON PLOTS SUBMERGED IMMEDIATELY AFTER BROADCAST SEEDING IN DATE-OF-SEEDING AND DEPTH-OF-SUBMERGENCE EXPERIMENTS AT THE BIGGS RICE FIELD STATION, BIGGS, CALIFORNIA, DURING THE YEARS 1922 AND 1923.

Seeding		Submergence		Acre yield in pounds			Compared with check	
Date	Method	Date	Depth, inches	1922	1923	Average	Gain	Loss
April 25	Broadcast on soil	April 25[a]	4	3295	2365	2830	419	....
April 25	Broadcast on soil	April 25[a]	6	3520[b]	3265[b]	3392	981	....
April 25	Broadcast on soil	April 25[a]	8	3265	2115	2690	279	....
May 5	Broadcast on soil	May 5	4	2605	2530	2667	156	....
May 5	Broadcast on soil	May 5	6	3290	2655	2972	561	....
May 5	Broadcast on soil	May 5	8	3075	2620	2847	436	....
May 15	Broadcast on soil	May 15	2	2850	2090	2470	59	....
May 15	Broadcast on soil	May 15	4	3695	2075	2885	474	....
May 15	Broadcast on soil	May 15	6	4250	2380	3315	904	....
May 15	Broadcast on soil	May 15	8	3645	1925	2785	374	....
May 16	Broadcast in water	May 15	4	3700	2190	2945	534	....
May 16	Broadcast in water	May 15	6	2805	1625	2215	....	196
May 16	Broadcast in water	May 15	8	4010	2130	3070	659	....
May 25	Broadcast on soil	May 25	4	3515	1560[c]	2537	126	....
May 25	Broadcast on soil	May 25	6	2785	1400[c]	2092	....	319
May 25	Broadcast on soil	May 25	8	3110	1460[c]	2285	....	126
April 25	Drilled	April 25[a]	6	1740	2392	2066	....	345
April 25	(Check) Drilled	June 15	6	3250	1572	2411	Check	....

[a] Submerged on April 28 in 1922.
[b] Yields slightly increased by an old fill.
[c] Affected by seepage.

EFFECT OF SOWING BROADCAST ON THE SOIL

In these experiments the rice was sown broadcast on the soil and the plots immediately submerged to the required depths. On plots submerged two inches considerable water grass emerged in 1923. On plots submerged four inches some water grass emerged, but plots submerged six and eight inches were practically free from water grass and sprangle-top (*Leptochloa fascicularis*) in both years. However, other water weeds appear to grow equally well at all depths of submergence. The same effect on water grass was noted for all dates of seeding. However, seepage on some plots started growth of water grass before the rice was sown and the plots submerged and these plots had more grass and poorer stands than those not effected by seepage.

EFFECT OF SOWING BROADCAST IN THE WATER

In this experiment the plots were submerged to the required depths and the rice was then sown broadcast in the water. The effect on water-grass control was the same in this experiment as when the rice was sown broadcast on the soil and the land immediately submerged. However, less seed usually is required to obtain good stands when rice is sown broadcast in the water than when it is sown broadcast on soil and then submerged.

EFFECT OF DRILLING SEED

On these plots the rice was drilled about one to one and one-half inches deep and immediately submerged to a depth of six inches. The water grass was effectively controlled, but poor stands and low yields of rice were obtained. The poor stands permitted the growth of red-stem (*Ammania coccinea*), annual sedge (*Cyperus difformis*), and cat-tail (*Typha latifolia*), and when these weeds are abundant they reduce the yields of rice.

EFFECT OF IRRIGATING DRILLED CHECK PLOTS IN THE ORDINARY WAY

The check plots were drilled and then irrigated and drained when necessary until thirty days after the rice emerged. They were then submerged six inches. These plots were rather foul with water grass and sprangle-top in both years, which no doubt reduced the acre yields.

CONCLUSIONS

The results of these experiments as shown in table 1 indicate that the following conclusions are justified:

(1) Rice should be sown broadcast comparatively early and immediately submerged to a depth of about six inches; (2) there is a slight advantage in yield, and a marked decrease in acre cost when rice is sown broadcast and immediately submerged, compared with rice sown broadcast in the water; (3) rice seed should not be drilled if the land is to be submerged immediately after seeding, because considerable seed rots if covered with both soil and water and this results in poor stands and usually in low yields; (4) rice sown broadcast and immediately submerged four, six or eight inches, or rice sown in the water for all dates of seeding except May 25, gave higher average yields, with one exception, than did the check plots.

COMPARISON OF AIR AND WATER TEMPERATURES

Rice is commonly sown in California between April 15 and May 15. At this time the temperatures of the air, water, and soil usually are too low for maximum germination. During the growing season of 1923, a soil thermograph was used to get temperature records on a plot sown broadcast and submerged six inches on April 25. The soil thermograph "torpedo" was placed horizontally on the surface of the soil beneath the six inches of water. The maximum and minimum air temperatures were taken daily under shade but with a free circulation of air. Records were taken from May to September, inclusive.

The average maximum temperature for the five-month period from May to September, inclusive was 87.8° F. for the air and 79.6° F. for the water. The average minimum temperature for the same five-month period was 56.4° F. for the air and 60.6° F. for the water.

The average maximum air and water temperatures for the months of May and June, during which time the rice was germinating and before it was large enough to shade the water effectively, were, for May, air 80.1° and water 82.7°, and in June, air 83.5° and water 85° F. The average minimum temperatures for the same months were for May, air 50.9° and water 53.7°, and for June, air 54° and water 58.6° F.

During July, August, and September, the water was almost completely shaded by the rice crop, and the average maximum air temperature for each month ranged from 9° to 18.7° F. higher than the average maximum water temperature. However, the average minimum water temperature for each month ranged from 1.5° to 6.7° F. higher than the average minimum air temperature.

The temperature readings in 1923 indicate that water to a depth of six inches maintains a higher and more uniform temperature than the air during the period of germination and early growth. For May the mean water temperature was 5.4° higher than that of the air, and for June it was 6.1° higher. This indicates that, in so far as temperature alone is concerned, conditions are more favorable for germination under six inches of water than they are in the atmosphere, or than they are presumably at the surface of the soil.

EXPERIMENTS ON SUBMERGENCE AFTER THE RICE HAS EMERGED

BROADCASTING AND DRILLING SEED COMPARED

These experiments were conducted in 1922 and 1923 on land that had been sown to rice and fallowed in the cultural experiments in alternate years from 1914 to 1921. In 1921 the land was fallowed. The 1922 crop was the fifth rice crop on this land in ten years. In the spring of 1922 the land was double-disked and harrowed. For the 1923 crop the land was spring plowed, double-disked, dragged, and harrowed. In both years these tillage operations prepared a good seedbed.

The annual and average acre yields from plots both broadcast and drilled, sown on two different dates and submerged at various depths after the rice emerged in the years 1922 and 1923, are shown in table 2. The annual yields of all except the check plots represent the average yields of two tenth-acre plots. The annual yields of the broadcast checks are for two plots irrigated by the ordinary method. The annual yields of the drilled check plots are the averages of four plots in all cases, except the yield recorded for May 5 seeding in 1923, which is for only two plots.

In these experiments alternate plots, usually inclosed by the same levees, were sown broadcast and drilled, respectively. In both years the rice was irrigated and the plots drained three times before the plots finally were submerged to the required depths. On the date of submergence the rice and water grass varied in height from one to two inches. In each year better stands and higher yields were obtained on plots sown on April 25 than from those sown on May 5.

The plots submerged two and four inches were foul with water grass and sprangle-top in both years. On plots submerged six and eight inches deep the water grass was controlled to a marked extent, but at such depths a good deal of rice was suffocated each season. There was some water grass and sprangle-top present on all plots in both years, but these grasses were much more abundant on the check plots and those submerged two and four inches than on the plots submerged six and eight inches. Submergence immediately after the rice was sown broadcast (table 1) was much more effective in the control of water grass than early submergence of drilled or broadcast rice after it had emerged.

The results of these experiments, as shown in table 2, indicate that (1) early seeding is better than late seeding; (2) two-inch and four-inch submergence results in higher yields than six-inch and eight-inch

submergence, due largely to the fact that much rice is suffocated by the water when submerged six and eight inches after it has emerged; (3) there is not a very marked difference in yields of drilled and broadcast plots, but yields from the drilled plots were slightly higher; and (4) this method of irrigation by deferred submergence of either

TABLE 2

ANNUAL AND AVERAGE ACRE YIELDS OF CALORO RICE OBTAINED ON PLOTS SOWN ON TWO DIFFERENT DATES, BOTH BROADCAST AND DRILLED, AND SUBMERGED AT VARIOUS DEPTHS AFTER THE RICE EMERGED, AT THE BIGGS RICE FIELD STATION, BIGGS, CALIFORNIA, IN THE YEARS 1922 AND 1923.

Seeding		Submergence		Annual and average acre yields in pounds			Compared with check	
Date	Method	Date	Depth, inches	1922	1923	Average	Gain, pounds	Loss, pounds
April 25	Broadcast	May 29[a]	2	2280	1830	2055	....	62
April 25	Drilled	May 29[a]	2	2690	2110	2400	173	....
April 25	Broadcast	May 29[a]	4	2580	2240	2410	293	....
April 25	Drilled	May 29[a]	4	2450	1985	2217	....	10
April 25	Broadcast	May 29[a]	6	2060	2095	2077	....	40
April 25	Drilled	May 29[a]	6	2480	1815	2147	....	80
April 25	Broadcast	May 29[a]	8	2300	1520	1910	....	207
April 25	Drilled	May 29[a]	8	2270	2145	2207	....	20
April 25	Broadcast	June 15	6	2590	1645	2117	....	....
April 25	Drilled	June 15	6	2450	2004	2227	....	....
May 5	Broadcast	June 8[b]	4	2050	1220	1635	425	....
May 5	Drilled	June 8[b]	4	2060	1675	1867	177	....
May 5	Broadcast	June 8[b]	6	1995	1210	1602	392	....
May 5	Drilled	June 8[b]	6	2085	1320	1702	12	....
May 5	Broadcast	June 8[b]	8	1825	905	1365	155	....
May 5	Drilled	June 8[b]	8	1735	825	1280	....	410
May 5	Broadcast	June 25	6	....	1210	1210	....	....
May 5	Drilled	June 25	6	1875	1505	1690	....	....

[a] Submerged on May 24 in 1923.

[b] Submerged on June 4 in 1923.

broadcast or drilled rice is inferior to continuous submergence immediately after the rice is sown broadcast, both in regard to water-grass control and to rice yields.

The rice plant apparently is unable to adjust itself to the sudden change from a dry or moist soil to a submerged life. Many of the young plants are suffocated in deep water (six and eight inches) and those which emerge are slow in regaining, if they ever fully regain, their normal vitality. However, when the rice seed germinates under

water and the seedlings emerge through the water, such plants appear to be more vigorous than plants grown by the ordinary method of irrigation.

SPRING PLOWING AND DISKING OF STUBBLE COMPARED

These experiments were conducted on land which had been alternately cropped to rice and fallowed in the cultural experiments from 1914 to 1921. The land produced a rice crop in 1921. The crop of 1922 was the sixth rice crop on this land in ten years.

In the springs of 1922 and 1923, one series of plots was double-disked and harrowed. A second series of plots was spring plowed, double-disked and dragged. These tillage operations prepared a good seedbed on the spring-plowed land, but a poor, hard, grassy seedbed on the disked stubble land.

The annual and average acre yields for these method-of-seeding experiments on spring plowed and on disked stubble land, submerged at various depths after the rice emerged in the years 1922 and 1923, are shown in table 3.

Each of the four check plots was a single tenth-acre plot each year, and irrigated in the ordinary way. The sizes and numbers of all the plots, except the check plots, are shown in footnotes to table 3.

In these experiments alternate plots, usually inclosed in the same levees, were broadcast and drilled. In both years the rice was irrigated and drained three times before the plots were submerged to the required depths. On the date of submergence the rice and water grass varied in height from one to two inches.

Each year the plots submerged two and four inches were quite foul with water grass and sprangle-top. On plots submerged six and eight inches the water grass was controlled to a certain extent, but in both seasons much rice was suffocated when submerged at these depths. While the plots submerged six and eight inches had much less water grass than plots submerged two and four inches, the stands of rice in the deeply submerged plots were too thin to make good yields. The stands on deep-water plots also were reduced in 1922 by injury from leaf miners and by the growth of spike-rush.

Spike-rush (*Eleocharis palustris*), locally known as wire grass, cat-tail (*Typha latifolia*), slender aster (*Aster exilis*), annual sedge (*Cyperus difformis*), and canary grass (*Phalaris*) were quite thick in both years on the disked stubble land. On the spring-plowed land very few of these weeds except the annual sedge were present.

The results of these experiments as shown in table 3 indicate that (1) shallow submergence is better than deep submergence with this method of irrigation, (2) this method of irrigation is inferior to continuous submergence immediately after broadcasting, both in

TABLE 3

ANNUAL AND AVERAGE ACRE YIELDS OF CALORO RICE OBTAINED ON SPRING-PLOWED AND ON DOUBLE-DISKED STUBBLE LAND IN PLOTS EITHER BROADCASTED OR DRILLED, AND SUBMERGED AT VARIOUS DEPTHS AFTER THE RICE EMERGED, AT THE BIGGS RICE FIELD STATION, BIGGS, CALIFORNIA, DURING THE CROP YEARS 1922 AND 1923.

Seed-bed preparation	Method of seeding	Submergence		Annual and average acre yields in pounds			Compared with check	
		Date	Depth	1922	1923	Average	Gain	Loss
Spring Plowed	Drilled	May 30	2	3510[a]	2115[a]	2812	492	....
Double Disked	Drilled	May 30	2	2430[a]	1395[a]	1912	17	....
Spring Plowed	Broadcast	May 30	4	2585[c]	2235[c]	2410	590	....
Double Disked	Broadcast	May 30	4	2180[c]	1335[c]	1757	422	....
Spring Plowed	Drilled	May 30	4	2460[c]	2605[c]	2532	212	....
Double Disked	Drilled	May 30	4	2455[c]	1510[c]	1982	87	....
Spring Plowed	Broadcast	May 30	6	2317[d]	2037[d]	2177	357	....
Double Disked	Broadcast	May 30	6	1803[d]	1177[d]	1490	155	....
Spring Plowed	Drilled	May 30	6	2248[e]	2042[e]	2145	....	175
Double Disked	Drilled	May 30	6	2048[e]	1383[d]	1715	....	180
Spring Plowed	Broadcast	May 30	8	1360[d]	1640[d]	1500	....	320
Double Disked	Broadcast	May 30	8	1037[d]	980[c]	1008	....	327
Spring Plowed	Drilled	May 30	8	1540[c]	1950[c]	1745	....	575
Double Disked	Drilled	May 30	8	1405[c]	710[c]	1057	....	838
Spring Plowed	Broadcast	June 16	6	1760[b]	1880[b]	1820	....	....
Double Disked	Broadcast	June 16	6	1780[b]	890[b]	1335	....	....
Spring Plowed	Drilled	June 16	6	2220[b]	2420[b]	2320	....	....
Double Disked	Drilled	June 16	6	2590[b]	1200[b]	1895	....	....

[a] Single fifteenth-acre plots.
[b] Single tenth-acre plots.
[c] Average of two tenth-acre plots.
[d] Average of three tenth-acre plots.
[e] Average of four tenth-acre plots.

control of grass and in rice yields, and (3) rice stubble should be plowed to help control such weeds as cat-tail, spike-rush, canary grass, slender aster, and perennial sedges.

The two-year average acre yield of all plots on spring-plowed land was 590 pounds higher than that of plots on the disked stubble land. This increase in yield indicates the necessity and value of plowing stubble land.

TABLE 4

Annual and Average Acre Yields of Fifth-acre Plots of Caloro Rice Obtained in the Rate-of-Seeding and Method-of-Irrigation Experiments at the Biggs Rice Field Station, Biggs, California, in the Years 1922 and 1923

Rate of Seeding (pounds)	Annual and average acre yields in pounds								
	Series 1		Series 2		Series 3		2-year average		
	Sown 5-5 Submerged 5-9 1922	Sown 5-10 Submerged 5-11 1923	Sown 4-26 Submerged 5-23 1922	Sown 4-30 Submerged 5-25 1923	Sown 4-26 Submerged 6-18 1922	Sown 4-30 Submerged 6-14 1923	Series 1	Series 2	Series 3
115	1840	2325	1350[a]	1830	1690	1355	2082	1590	1522
130	1860	2285	2650	2300	2925	1805	2072	2475	2365
150	2980	2075	2735	2140	2660	1730	2527	2437	2195
175	1815[b]	1800[b]	2380	1690	2295	1530	1807	2035	1912
190	3135	2555	2605	1845	1720	1435	2845	2225	1577
Average	2326	2208	2344	1961	2258	1571			

[a] Yields reduced by injury from leaf miners.

[b] Yields probably reduced by non-uniform land.

EXPERIMENTS ON RATE OF SEEDING AND METHOD OF IRRIGATION

These experiments were conducted on land previously used in the irrigation experiments. The land was fallowed in 1921. The 1922 crop was the sixth rice crop on this land in nine years. In the spring of 1922 the land was double-disked twice, harrowed, and dragged. For the 1923 crop the land was spring plowed, double-disked, harrowed, and dragged. These tillage operations prepared a good seedbed each year. The annual and average acre yields for these rate-of-seeding and method-of-irrigation experiments in the years 1922 and 1923, are shown in table 4.

On series 1 in table 4 the rice was sown broadcast and the plots immediately submerged six inches. On series 2 the rice was drilled and irrigated and drained twice before the rice emerged. It was then submerged six inches. On series 3 the rice was drilled and then irrigated and drained several times, and then was submerged six inches, thirty days after the rice emerged.

The plots on which the rice was sown broadcast and immediately submerged (series 1) were practically free from water grass and sprangle-top in both years. The annual sedge was quite thick each year, due to thin stands of rice. Plots on which the rice was drilled and irrigated and drained twice before submergence (series 2) had considerable water grass and sprangle-top present in both seasons. The plots irrigated in the old way (series 3) were quite foul in 1922 and very foul in 1923.

The highest average acre yield on series 1 was obtained from the 190-pound rate of seeding and on series 2 and series 3 from the 130-pound of rate of seeding. The average acre yield of all plots on series 1 and on series 2 was higher than that for the plots on series 3 in both years.

EXPERIMENTS ON SEEDBED PREPARATION

The land on which these experiments were conducted had grown six rice crops in nine years and was very foul. It produced a crop in 1921 by continuous submergence. In the springs of 1922 and 1923 the land was spring plowed, double-disked and dragged, except for two plots which received no seedbed preparation in 1922.

The rice either was sown broadcast and immediately submerged to the required depths, or the land was submerged and the rice then

sown broadcast in the water. The annual and average acre yields from these seed-bed-preparation experiments in the years 1922 and 1923 are shown in table 5.

TABLE 5

ANNUAL AND AVERAGE ACRE YIELDS OF CALORO RICE OBTAINED BY BROADCAST SEEDING ON WELL-PREPARED AND UNPREPARED SEEDBEDS, WITH DIFFERENT DEPTHS OF SUBMERGENCE, AT THE BIGGS RICE FIELD STATION, BIGGS, CALIFORNIA, IN THE YEARS 1922 AND 1923.

Seed-bed Preparation	Seeding		Date of Submergence	Depth of Submergence, inches	Annual and average acre yields in pounds		
	Date	Method			1922	1923	Average
Good	May 9	Broadcast	May 11	4	3492[a]	2148[a]	2820
Good	May 9	Broadcast	May 11	6	3553[b]	1959[b]	2756
Good	May 15[c]	Broadcast in water	May 11	6	3144[d]	1941[d]	2542
Good	May 9	Broadcast	May 11	8	3589[b]	2661[e]	3125
Good	May 9	Broadcast	May 11	6	2590[f]	2030[f]	2310
None	May 9	Broadcast	May 11	6	2768[g]	....	....
None	May 15	Broadcast in water	May 11	6	2024[g]	....	....

[a] Yields of single half-acre plots.
[b] Average yields of two half-acre plots.
[c] Sown on May 14 in 1923.
[d] Yields of single plot.
[e] Average yields of three half-acre plots.
[f] Average yield of two third-acre plots sown at rate of 200 lbs. per acre.
[g] Yield of single fourth-acre plots.

EFFECT OF GOOD PREPARATION

On prepared seedbeds there was very little water grass on plots submerged four, six, and eight inches, except for the white or ''Japanese'' water grass, which was present to a considerable extent on all plots in 1921 and 1922, and was sufficiently thick in 1923 to materially reduce rice yields. The results indicate that white water grass cannot be controlled by continuous submergence to these depths. Observations along ''barrow pits'' at the base of the levees, and in dead furrows, indicate that water ranging from ten to fifteen inches deep does aid materially in controlling white water grass. At such depths, however, it is difficult to get good stands of rice and also it is impracticable to hold the water so deep. It appears, therefore, that white water grass when thin should be pulled to prevent spreading.

EFFECT OF NO PREPARATION

The plots sown in 1922 on stubble land without seedbed preparation were quite foul with spike-rush, cat-tail, slender aster, and canary grass. Water grass also was much thicker on these than on plots which were spring plowed. Some water grass usually germinates in the spring before the land is prepared for seeding and such plants must be killed by cultivation as it is practically impossible to control or suffocate them with water six to eight inches deep.

CONTROL OF CAT-TAIL BY HEAVY SEEDING

Seeding at the rate of 200 pounds per acre on land badly fouled with cat-tail did not check the growth of the cat-tail. However, it has been observed during past years that on clean land good stands of rice are very helpful in preventing cat-tail from becoming established. Cat-tails usually first appear in a field where the stands of rice are poor, that is, along the levees and on low land where it is difficult to secure good stands of rice.

CONCLUSIONS

The results of these experiments indicate that (1) it is not profitable to grow rice on unprepared seedbeds because of low yields, caused in part, at least, by competition with spike-rush, cat-tail, slender aster, canary grass, and water grass; (2) sowing in the water has no advantage over sowing broadcast and immediately submerging the land, except that less seed usually is required to secure good stands when sown in the water, but this saving in seed probably is more than offset by the increased cost of seeding in water; and (3) eight inches of water is the best depth to hold continuously after the rice is sown broadcast.

EXPERIMENTS ON RATES OF SEEDING WITH THREE VARIETIES

The rate-of-seeding experiment which was started in 1921 included three varieties of rice, Selection No. 175, Caloro, and Wataribune, C. I. No. 1561. The land used for this experiment was fallowed in 1920. The 1921 crop was grown on fallow land, and the 1922 and 1923 crops were grown on spring-plowed stubble land.

Each variety and rate of seeding was located on the same plot each year. A reasonably good seedbed was prepared before seeding. The

TABLE 6

ANNUAL AND AVERAGE ACRE YIELDS FROM TENTH-ACRE PLOTS OF SELECTION NO. 175, CALORO, AND WATARIBUNE VARIETIES OBTAINED IN A RATE-OF-SEEDING EXPERIMENT AT THE BIGGS RICE FIELD STATION, BIGGS, CALIFORNIA, DURING THE THREE-YEAR PERIOD FROM 1921 TO 1923, INCLUSIVE

Rate of Seeding pounds	Annual and average acre yields in pounds											
	Selection No. 175			Caloro			Wataribune C. I. (1561)			3-year average		
	1921	1922	1923	1921	1922	1923	1921	1922	1923	Selection No. 175	Caloro	Wataribune
85	1880	2450	2450	2380	2690	1650	2150	2340	2140	2260	2240	2210
100	2660	2560	2140	2630	3260	2640	2800	2650	2310	2453	2843	2587
115	2710	2920	2650	2460	3170	2550	3210	3170	2790	2760	2727	3057
130	2740	3630	3350	2510	2980	2470	3160	3160	2680	3240	2653	3000
150	3030	3510	3540	2860	3180	2600	3640	3110	2620	3360	2880	3123
175	2450	3820	3280	3080	2900	2917	3290	2770	2420	3183	2966	2827
Average	2578	3148	2902	2653	3030	2471	3042	2867	2493	2876	2718	2801

rates of seeding for each variety ranged from 85 to 175 pounds per acre. The rice on all plots was sown with a drill on the same date each year.

After seeding, all plots were irrigated and drained at frequent intervals until thirty days after the rice emerged. The land then was submerged about six inches and the water held at this depth until the land was drained for harvest. The water grass which appeared was hand-pulled before it reached maturity.

The annual and average acre yields, for the rate-of-seeding experiment with Selection No. 175, Caloro, and Wataribune, during the three-year period from 1921 to 1923, inclusive, are shown in table 6.

Those who are familiar with cereal crops know that the maximum yield of a given variety is not likely to be obtained from the same rate of seeding each year. However, in a period of years each variety probably will produce its maximum average yield at some constant rate of seeding. It is not possible to conduct a rate-of-seeding experiment for each variety, due to the large number of varieties. Recommendations as to the best rate of seeding, therefore, usually are based on the results of rate-of-seeding experiments with one or two of the leading commercial varieties grown in a given area.

The rate of seeding for rice is influenced by many factors, some of the most important of which are variety, age of seed, quality of seed, date of seeding, depth of seeding, method of seeding, condition of the seedbed, method of irrigation and kind of land, whether new or old, rich or poor.

In table 6 it will be noted that, for Selection No. 175, the average acre yield increased with each increased rate of seeding from 85 to 150 pounds per acre. For Caloro the average yield did not show consistent increases for increased rates of seeding. However, the highest average yields were obtained from the 175-pound and 150-pound rates. The average acre yields for Wataribune show consistent increases with increased rates of seeding from 85 to 150 pounds per acre, except for the 115-pound rate.

The three-year average yield, at all rates of seeding, for Selection No. 175 was 2876 pounds, for Caloro 2718 pounds, and for Wataribune 2801 pounds per acre.

These results indicate that on old land rice probably should be sown at the rate of 150 pounds per acre.

SUMMARY

1. Rice sown broadcast and immediately and continuously submerged, or rice sown broadcast in the water and kept submerged thereafter, appears to have three distinct advantages over rice irrigated in the old way: (1) it matures from seven to ten days earlier than rice irrigated in the old way, depending somewhat upon the date of seeding, for there is less difference from early than from late dates of seeding; (2) continuous submergence does control the most common forms of water grass and sprangle-top; (3) the rice appears to develop into better plants than those grown by the old method of irrigation.

2. When rice is drilled and immediately submerged it appears that considerable seed rots, and this often results in poor stands and low yields of rice.

3. When rice is drilled or broadcast and irrigated lightly for two to four weeks to bring it up before it is permanently submerged, shallow submergence at two and four inches apparently does not control the water grass. Deep submergence at six and eight inches does aid in control of water grass, but such depths also suffocate so much rice that low yields are produced.

4. The results indicate that good seedbed preparation pays. It does not pay to grow rice on a seedbed prepared merely by disking stubble land, because such weeds as spike-rush, slender aster, cat-tail, canary grass, and perennial sedge reduce the yields below profitable limits. Good spring plowing aids materially in the control of these weeds.

5. The results indicate that rice should be sown at a higher rate when it is grown by continuous submergence immediately after broadcasting than when it is grown by the old method of irrigation.

6. The results indicate that on land foul with cat-tail a heavy rate of seeding (200 pounds per acre) does not help to control the cat-tail. But good stands of rice apparently do aid in preventing cat-tail from entering a clean rice field.

7. It appears that less seed is required to obtain good stands when rice is sown broadcast in the water than when sown broadcast on the soil and then submerged. This probably is due to the fact that when sown broadcast and then submerged considerable seed is covered by slacked clods and rots before germination.

8. The results indicate that, on old land, rice probably should be sown at the rate of 150 pounds per acre when grown by the old method of irrigation.

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